LA-UR-21-28836
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Title: Time-resolved spot size measurements at DARHT

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Intended for: Report

Issued: 2021-09-07

Time-resolved spot size measurements at DARHT

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and
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October 3-4, 2007

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Radiography of hydrodynamic experiments is evolving toward better time resolution.

- **Single-pulse imaging – (beginning in 1960s)**
  - **1963, SMOG (Diode) at AWRE (UK)**
  - **1963, PHERMEX (RF) at LANL (US)**
  - **1965, VIM (Betatron) at VNIIEF (Ru)**
  - **1982, FXR (LIA) at LLNL (US)**
  - **1999, DARHT-I (LIA) at LANL (US)**
  - **2000, AIRIX (LIA) at PEM (Fr)**
- **Multiple-pulse imaging – (beginning in 1980s)**
  - **1989, VIM (3-pulse Betatron) at VNIIEF (Ru)**
  - **1996, PHERMEX (2-pulse RF) at LANL (US)**
  - **2008, DARHT-II (4-pulse LIA) at LANL (US)**
- **Continuous imaging – (beginning soon?)**
  - **200?, DARHT-II (1.6-μs LIA) at LANL (US)**

A parallel evolution of time-resolved radiographic-spot measurements is necessary.

- **Single-pulse spot measurements**
  - Roll bar, Pinhole, Penumbral (film or phosphor) at all labs
- **Multiple-pulse spot measurements**
  - Pinhole (LLNL CAM-X and NSTec TRSS w/gated ccds) at LANL
- **Continuous imaging of radiographic spots**
  - Pinhole (TRSS w/streak) at LANL
  - Rollbar (streak) at SNLA

Time-resolved spot measurements are crucial for understanding beam-target interactions to improve the time-integrated spot size !

A Time Resolved Spot Size (TRSS) camera under development for DARHT-II will be able to operate in either multi-pulse or continuous mode.

3-tons of tungsten shielding

4-ea PIMax2 intensified CCD cameras
-- radiation star suppression

4-ea scintillators (LYSO & BC400)

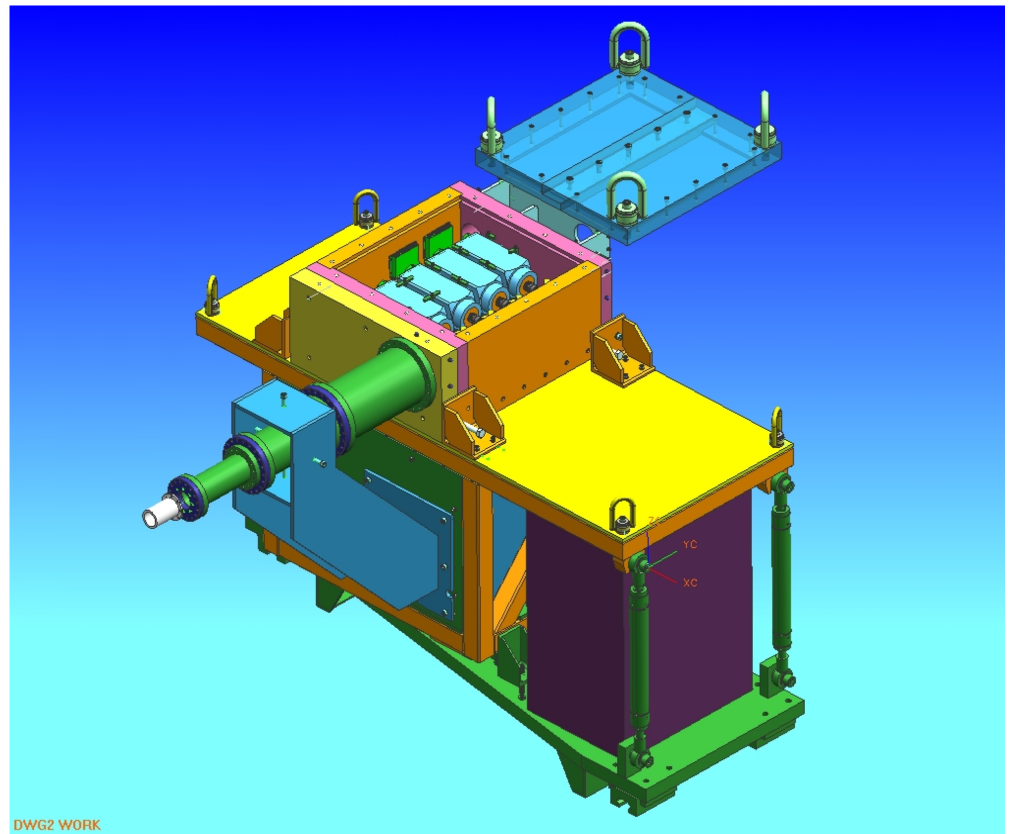
Conical pinhole assembly

Extendable snout
-- adjustable magnification

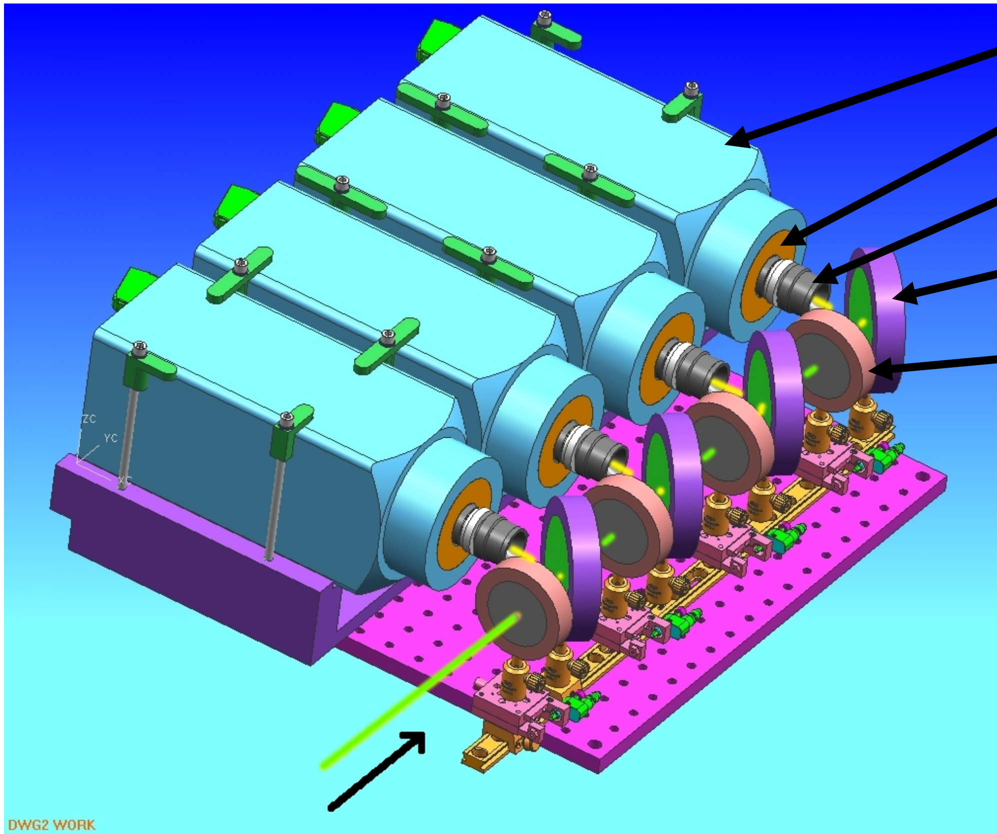
Dedicated resident computer

Ethernet communication with control room

Hexapod support structure
-- ease of alignment



National Security Technologies LLC



PIMAX2 Intensified CCD

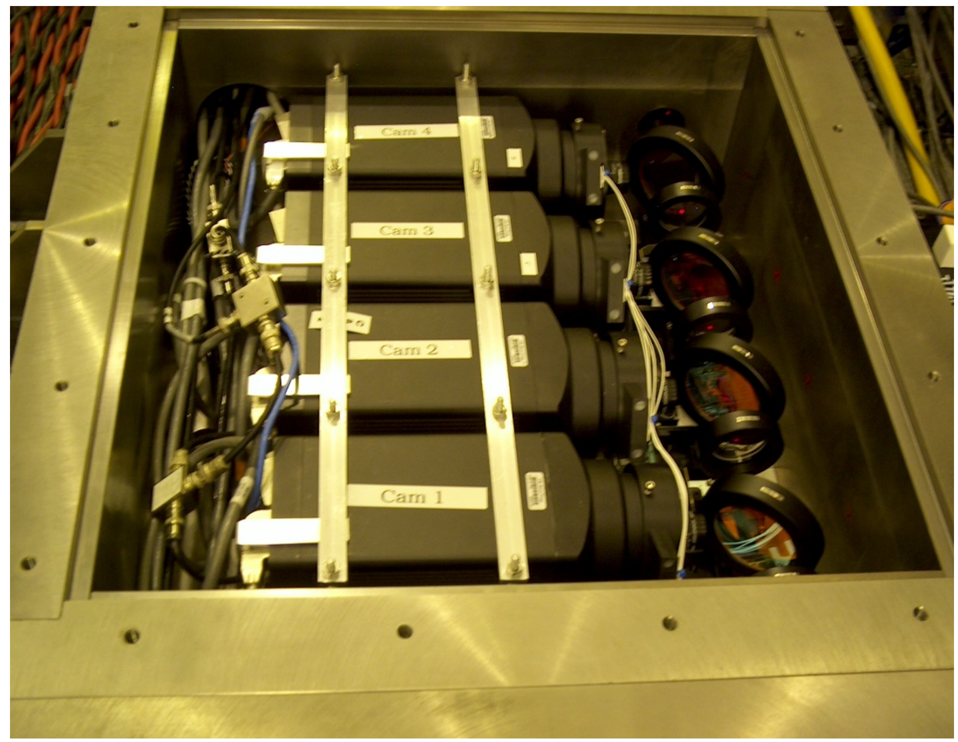
Electroluminescent Screen

CCD lens

45° turning mirror

Scintillator (BC400, LYSO, or W matrix)

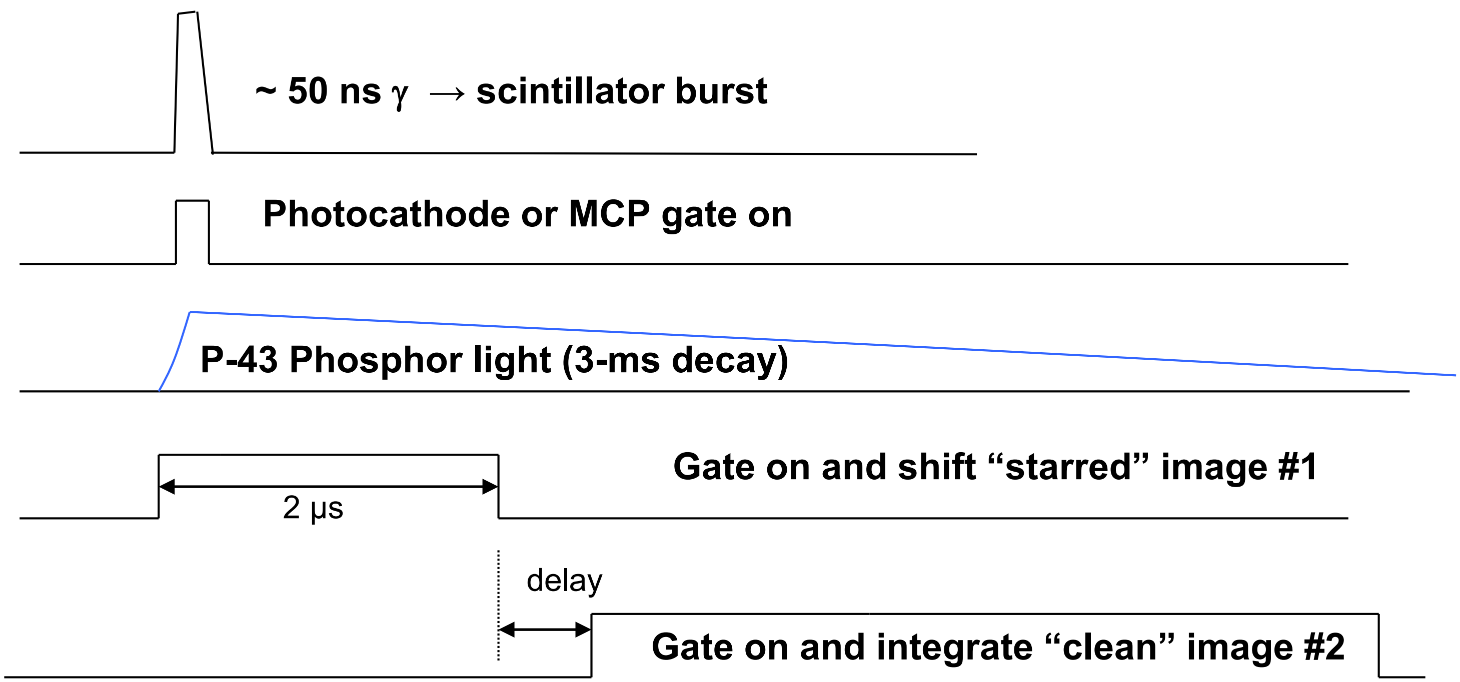
The camera package was modeled in detail to ensure fit and accessibility when installed in the tungsten shielding box

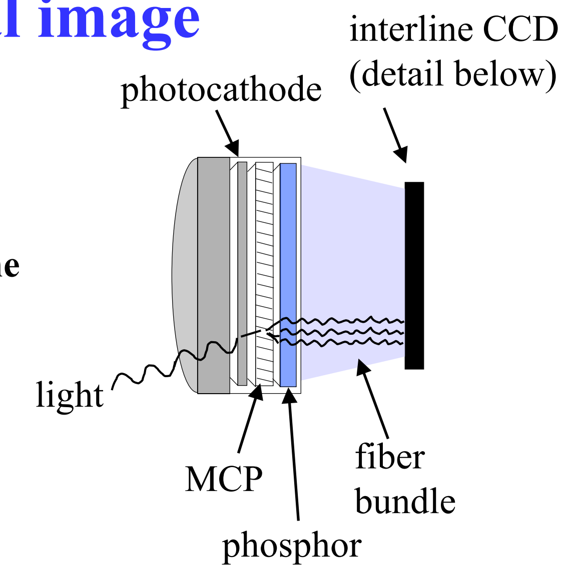


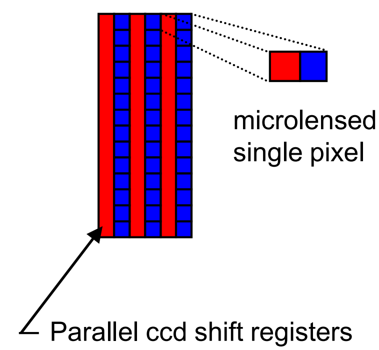
Camera package installed in the tungsten box

Radiation “Star” and background is reduced using dual image format interline CCD device

- **Gamma produced photoelectrons are generated everywhere in CCD silicon**
  - in both the “opaque” parallel shift register wells <u>and</u> the open photodiode region
- **Gating on image #1 and shifting collects and sweeps the gamma induced charge, leaving the clean photodiode region to accept only phosphor light when image #2 gate is turned on.**







interline CCD
architecture detail

“Star” removal was tested at the Santa Barbara Febetron

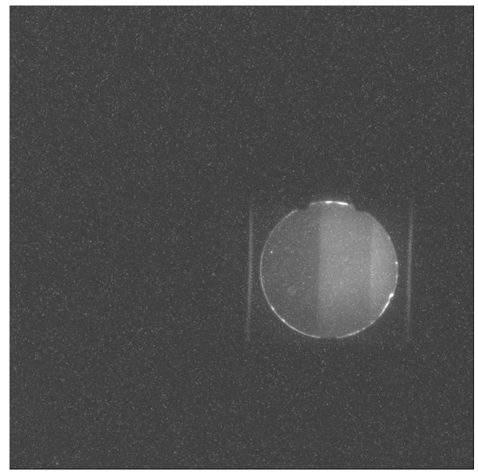
- 2-MeV bremsstrahlung through step wedge onto BC-400

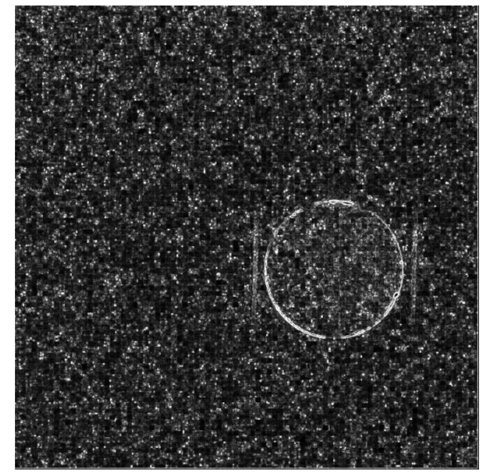
- PiMax2 intensified CCD camera in full radiation field (no turning mirror)

Raw data

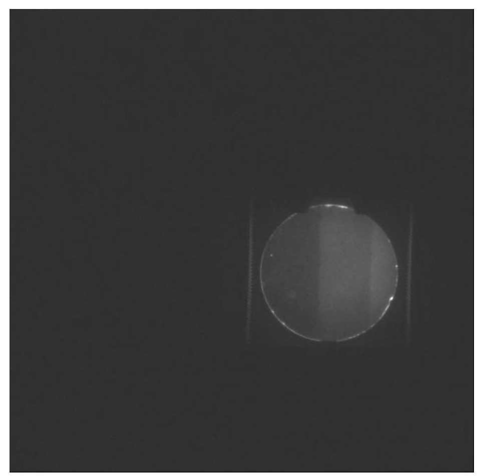
Edge Enhanced

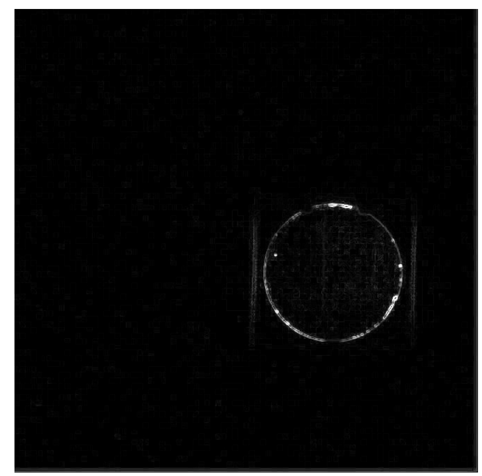
“Starred” Frame # 1





“Clean” Frame # 2





The TRSS pinhole assembly minimizes bleed-through and scatter backgrounds.

Made from 18 gm/cc Tungsten

Total thickness is 10.2 cm

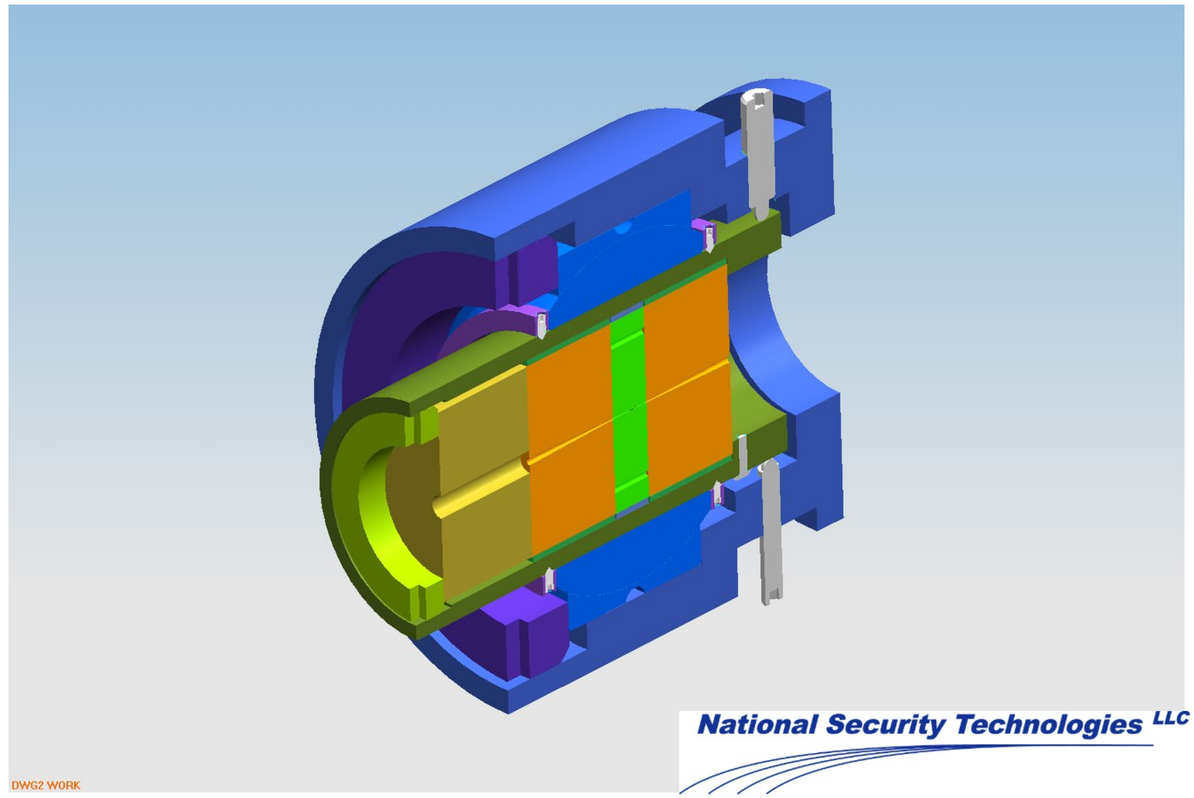
Central disk is 1.2 cm thick

200μm diameter pinhole

2.5 degree conical collimators

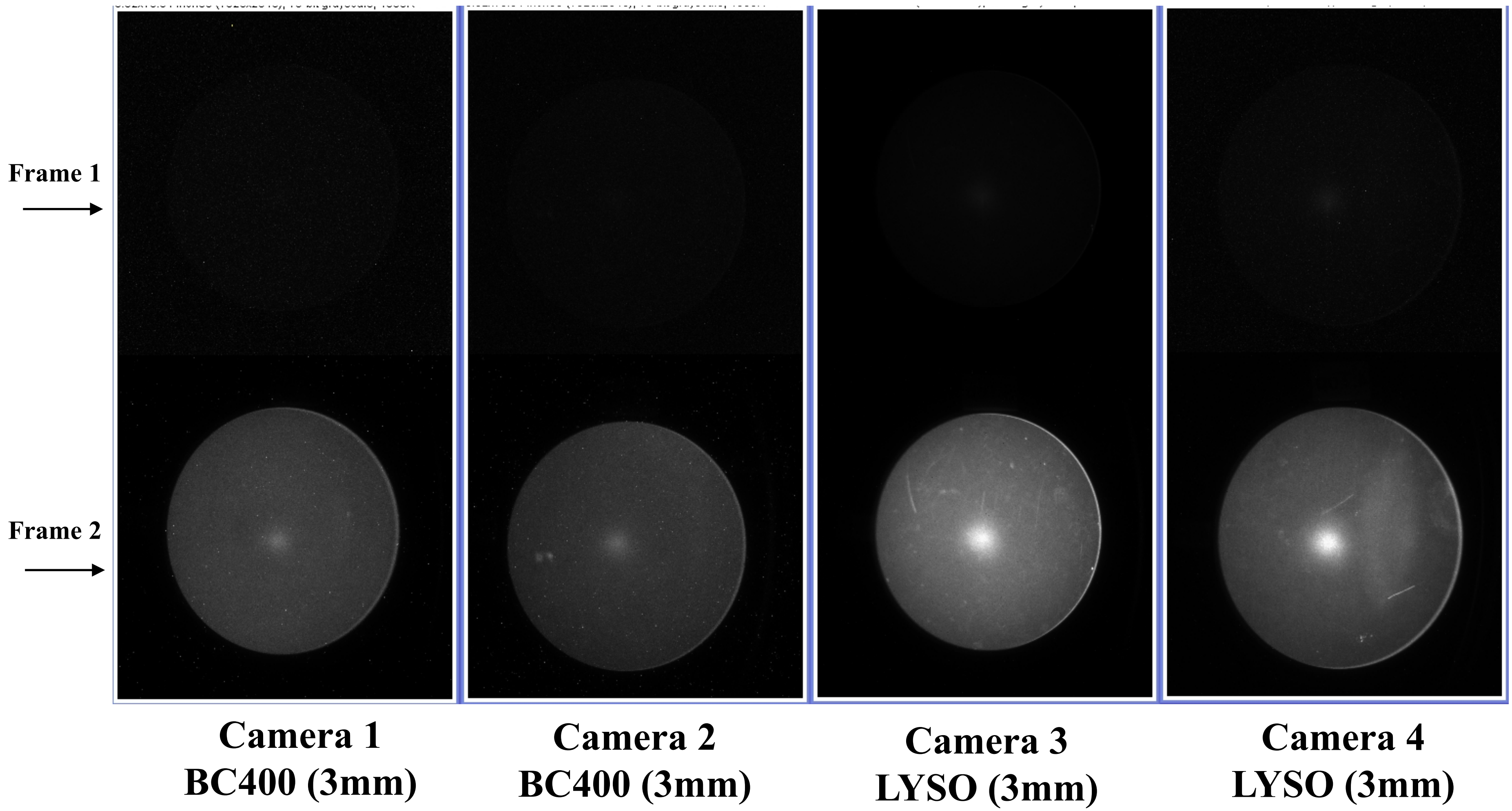
Gimbal mount

EDM fabrication

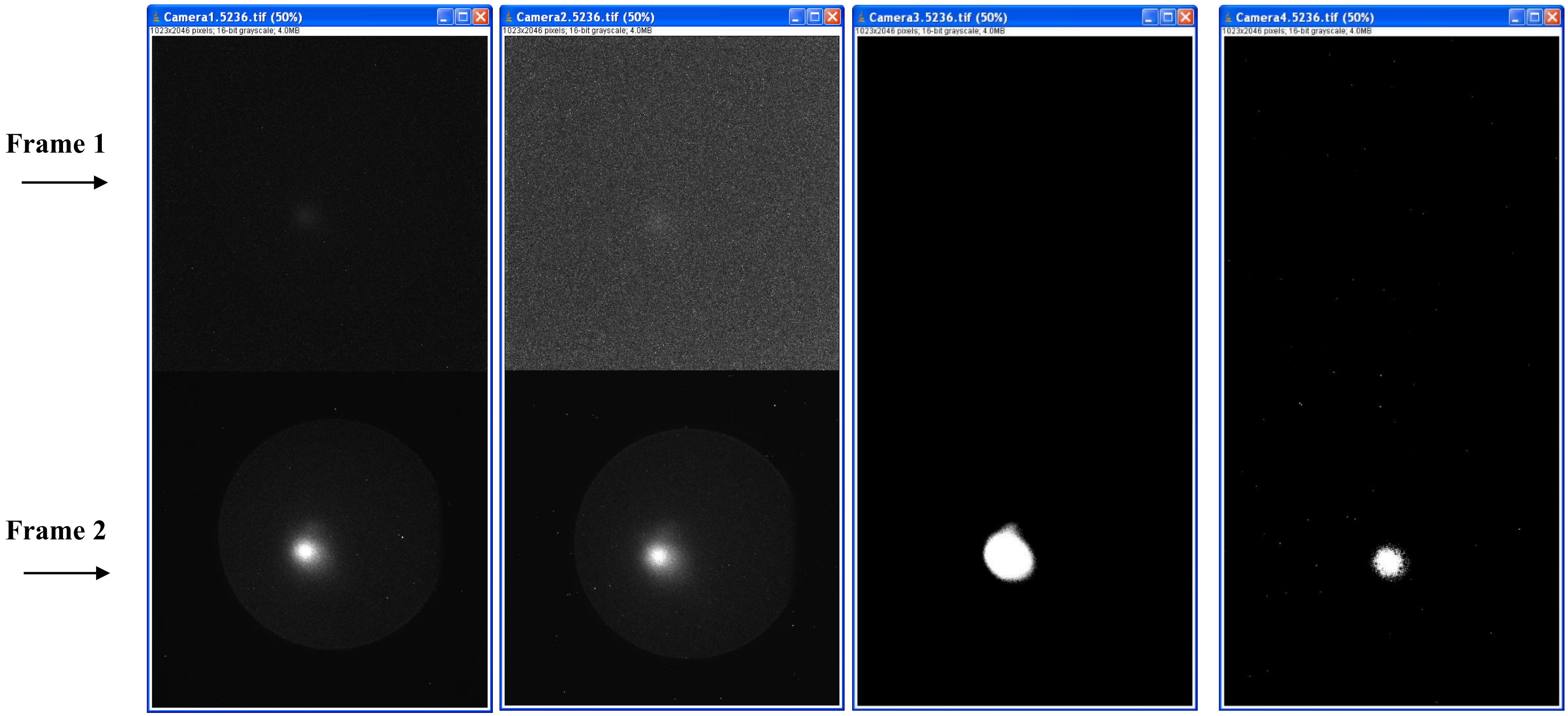


Extensive MCNP simulations were used in the design process.

TRSS was first tested on the 8-MeV scaled DARHT-II accelerator single-pulse targets December 11, 2006



We improved the signal to background ratio for the next (and final) 8-MeV test on February 5, 2007



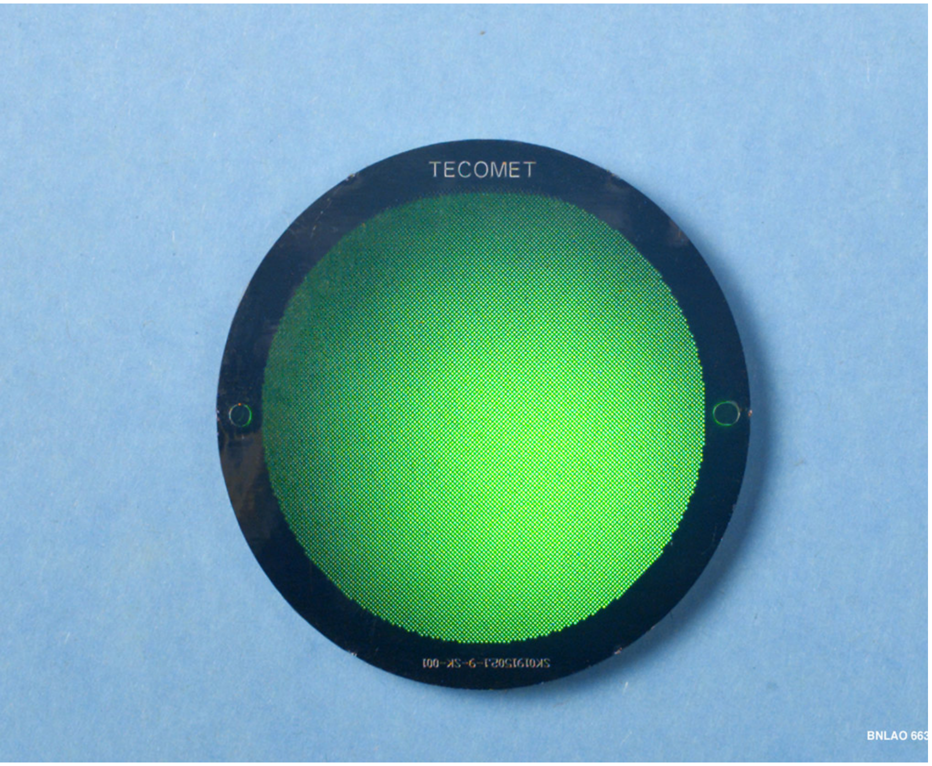
Camera 1
BC400 (5mm)

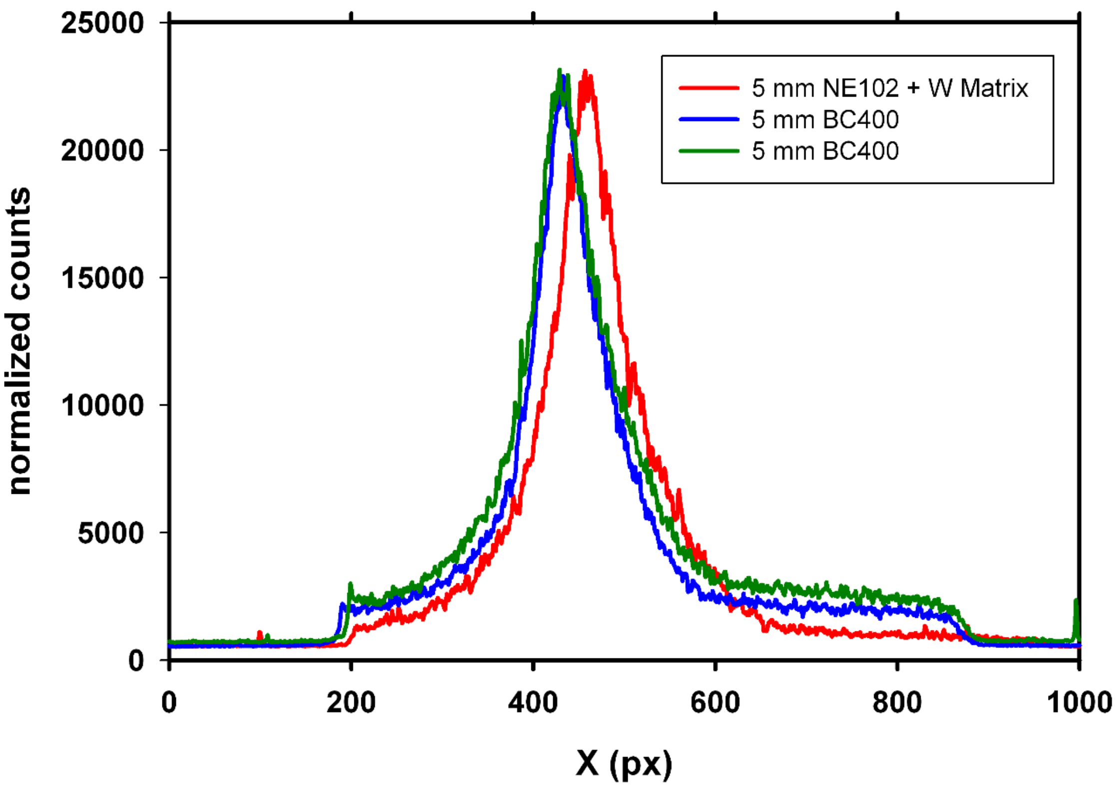
Camera 2
BC400 (5mm)

Camera 3
LYSO (3mm)

Camera 4
W-Matrix (5mm)

We obtained a significant improvement of signal to background with the NE-102 embedded in a tungsten matrix.

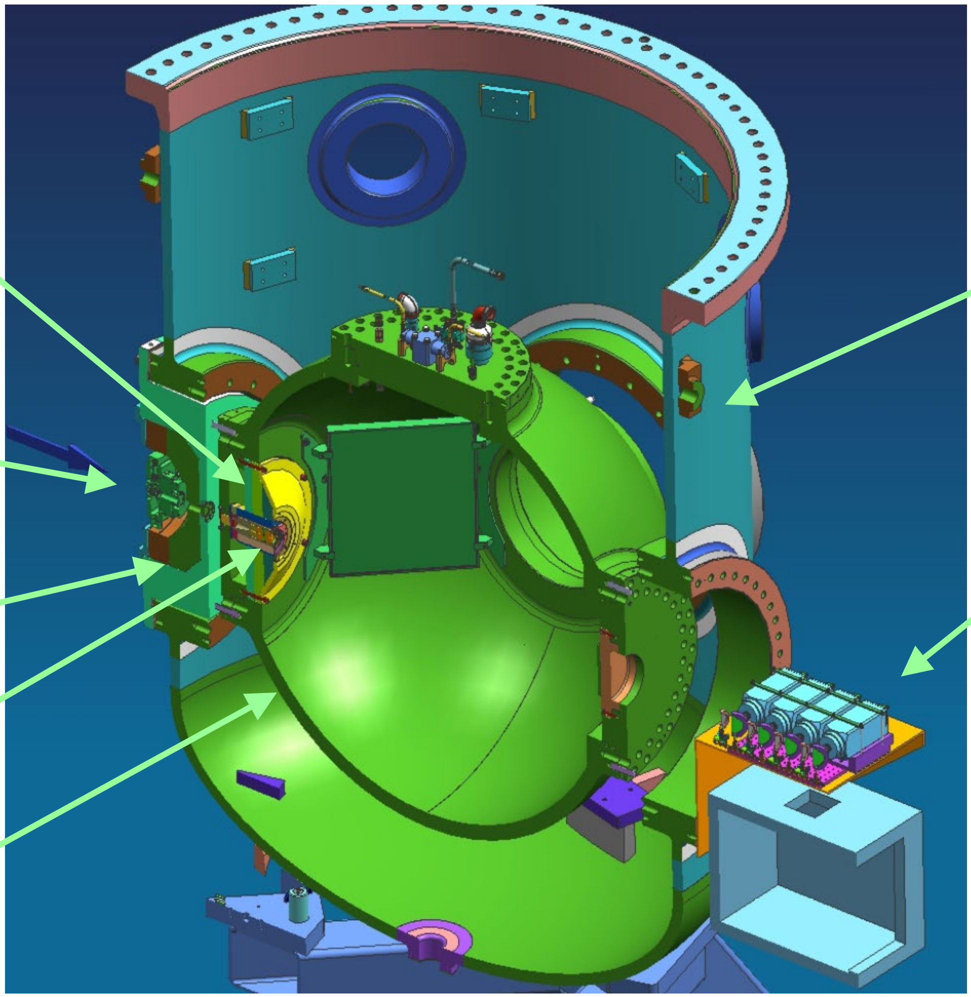




- 5 mm thick tungsten matrix
- pixel pitch 0.355 mm
- 0.25 mm NE102 plastic fiber

Matrix Signal to Background ratio enhanced by ~3 over same thickness of bare scintillator

The bare TRSS camera package will be mounted outside of the safety vessel and will rely on vessel shielding for spot-size measurements on DARHT-II.

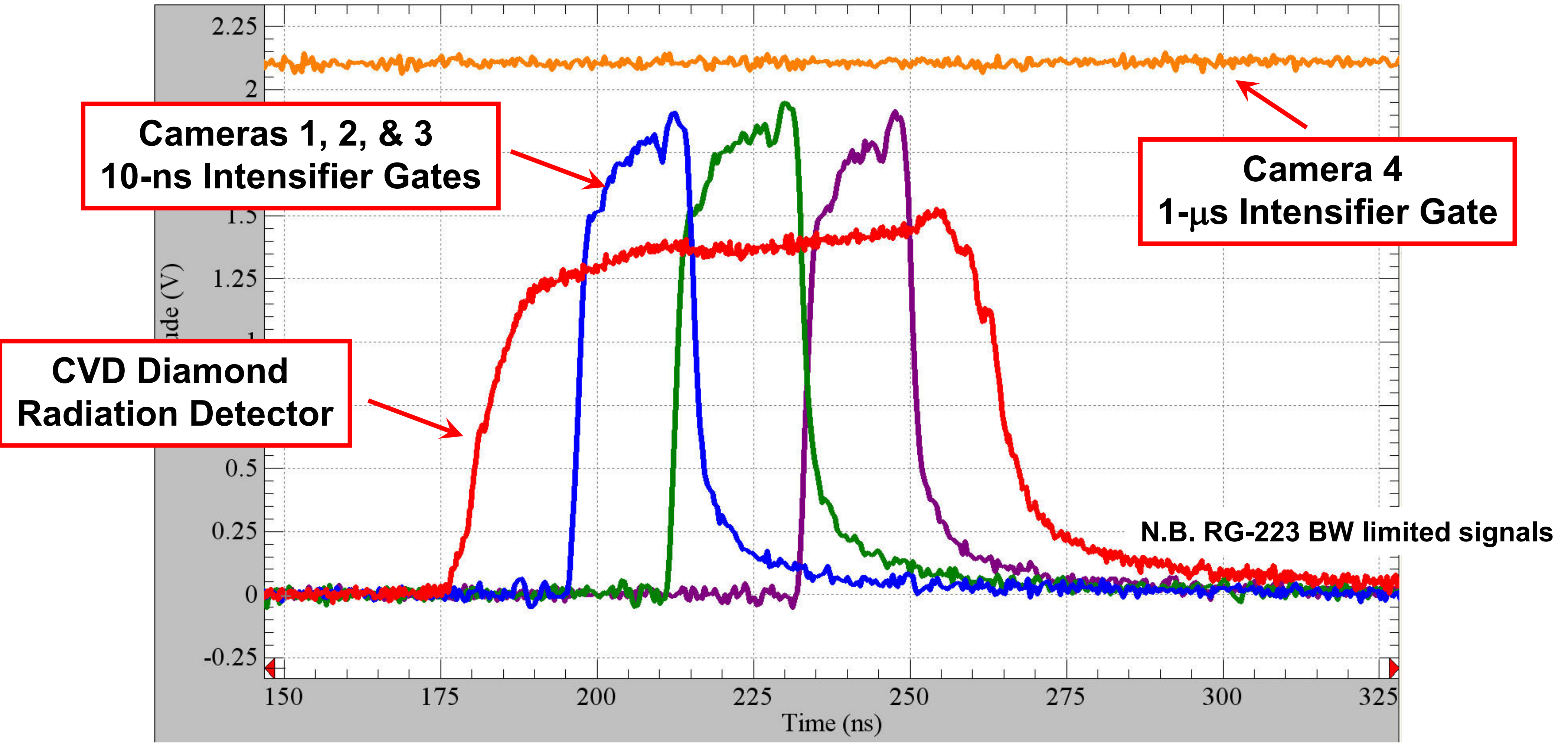


TRSS-Lite :

~ 4:1 Magnification

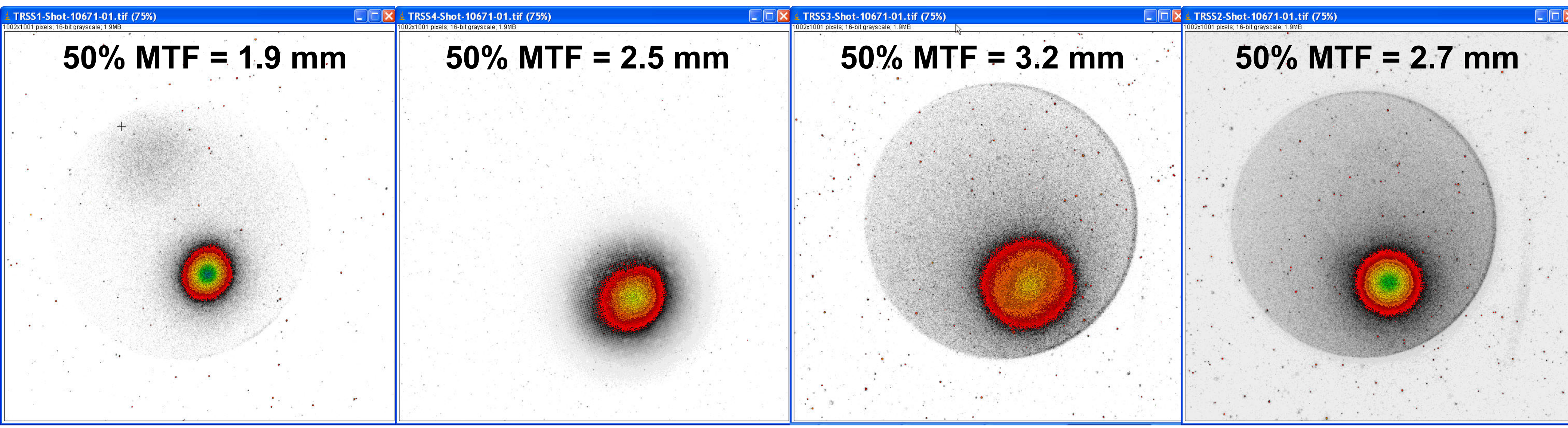
- Scintillators
- Optics
- Cameras
- Controllers
- EMP shielding

TRSS has been tested in the vessel-shielding geometry by time-slicing the 1.7-kA, 60-ns, 19.8-MeV DARHT-I radiographic spot.



Time-resolved images of the DARHT-I spot show that it grows from time-varying ion focusing.

SHOT 10671 **10-ns Gates** **1-μs Gate**



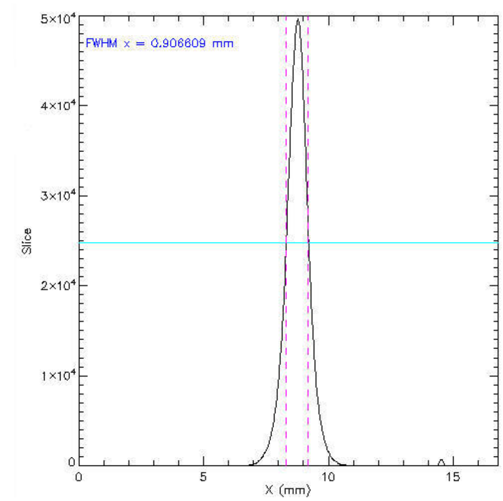
525 ns 20 ns 545 ns 20 ns 565 ns 0 ns

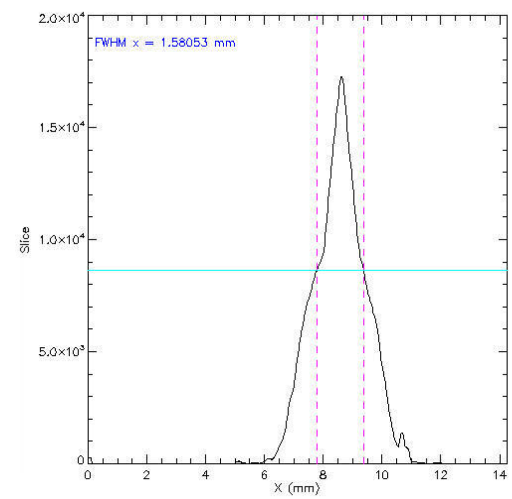
Relative gate delays

Correlation of temporal evolution of spot shape with physics simulations can provide guidance for spot-growth mitigation.

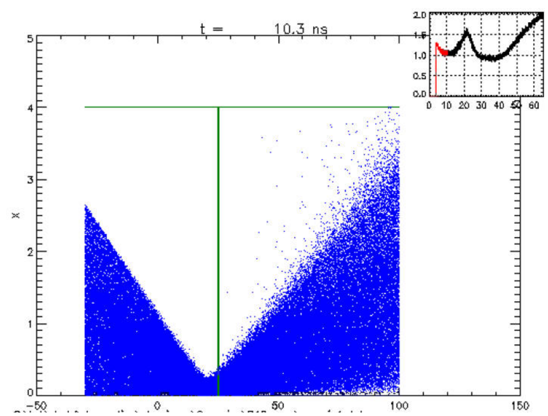
~ 10 ns **~ 50 ns**

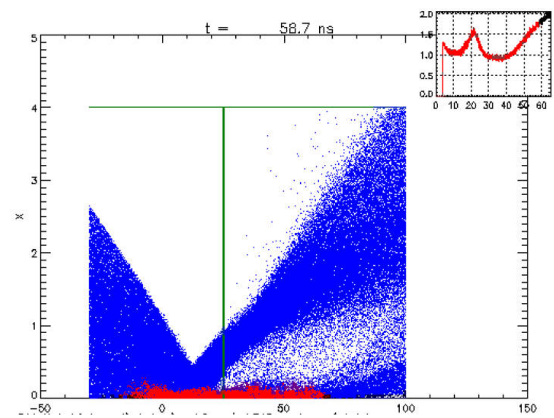
TRSS Profiles for shot 10671



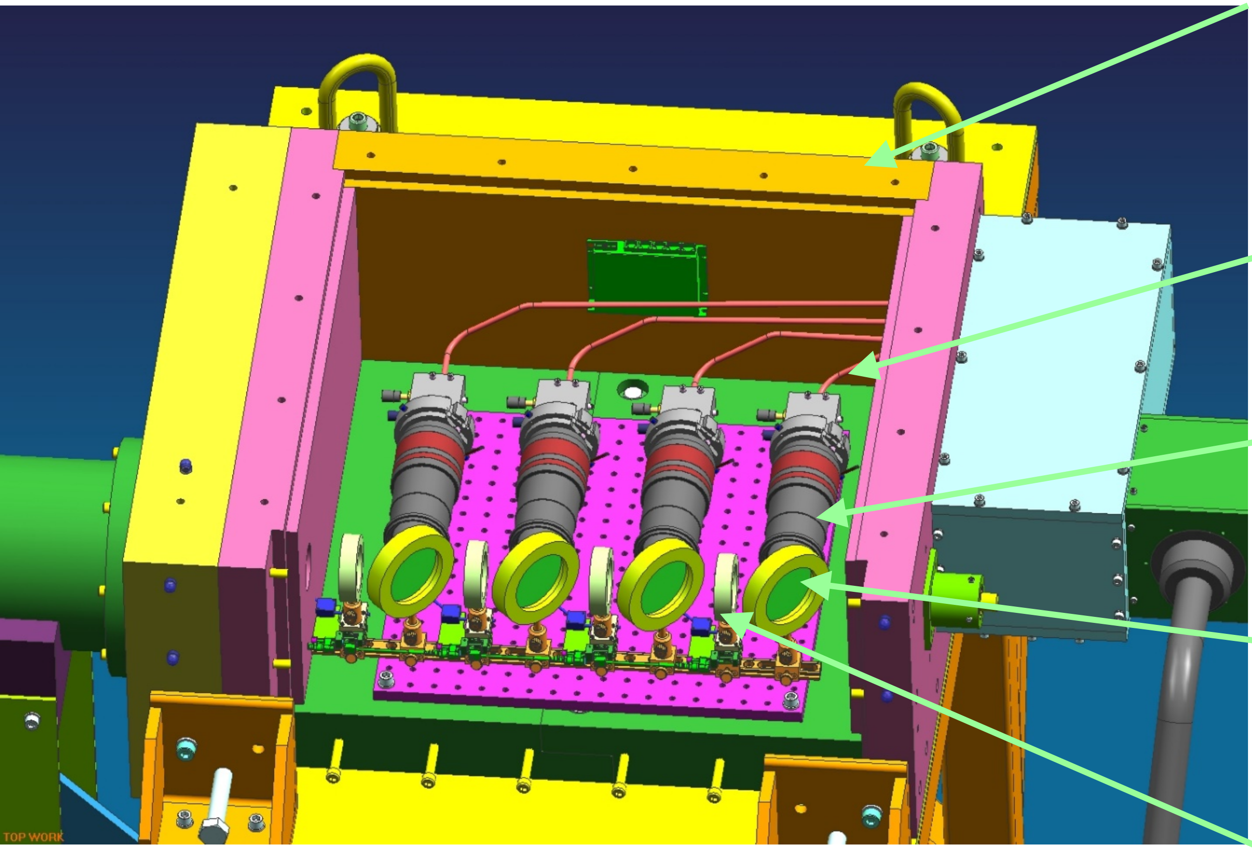


LSP Simulations
(ca 2001 experiments)
Courtesy of Tom Hughes

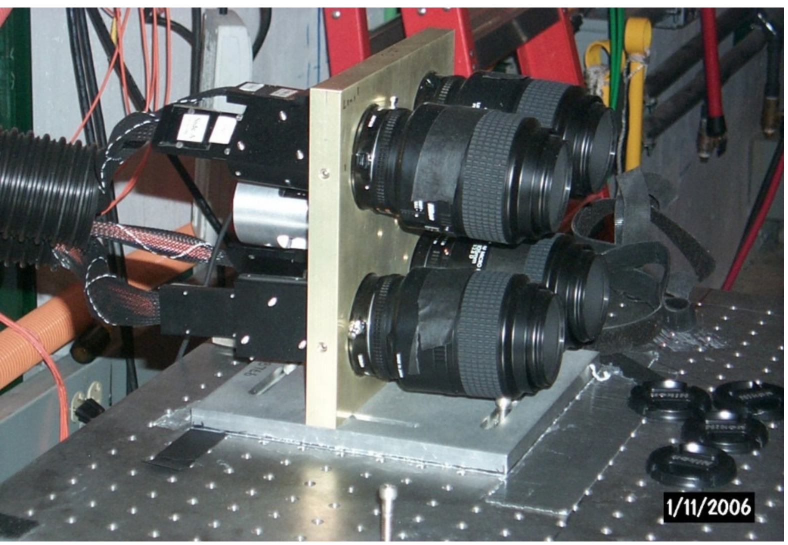


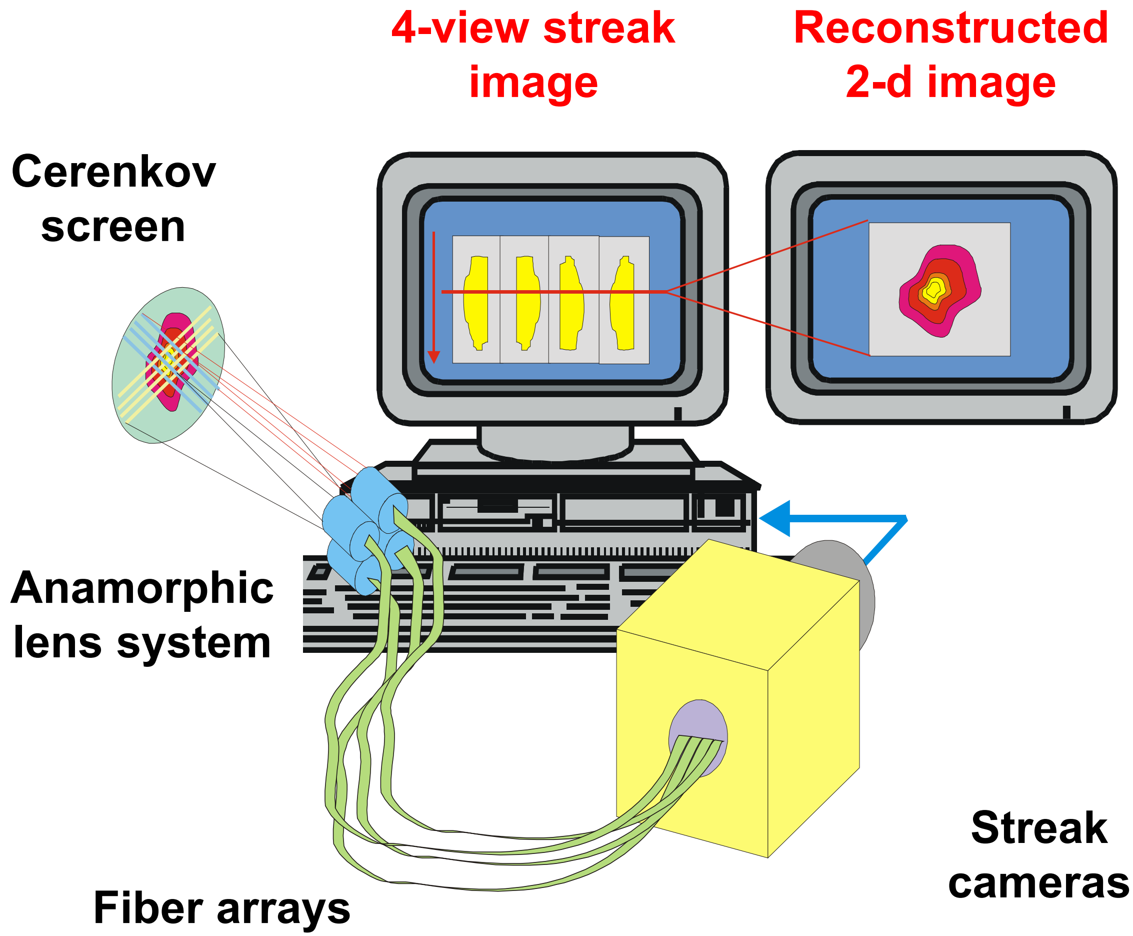


The TRSS tungsten-shielded platform has been designed to easily convert to continuous imaging using our 4-view anamorphic streak imaging system.



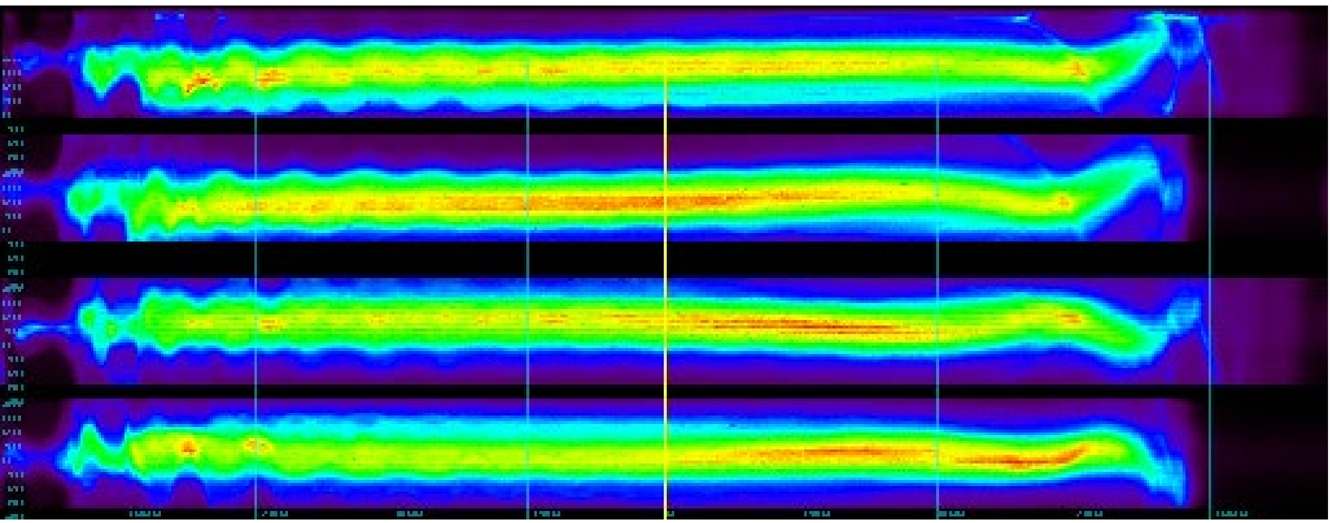
The 4-view anamorphic streak system developed by NSTec provides a continuous record of 2-D images of the DARHT-II beam profile.





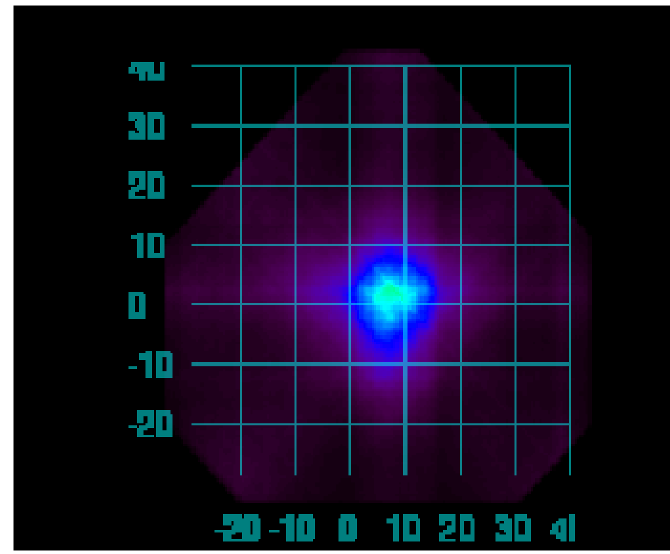
Continuous imaging of the beam profile using Cerenkov emission is now a routine diagnostic on DARHT-II.

Shot 1919



2.3 μs

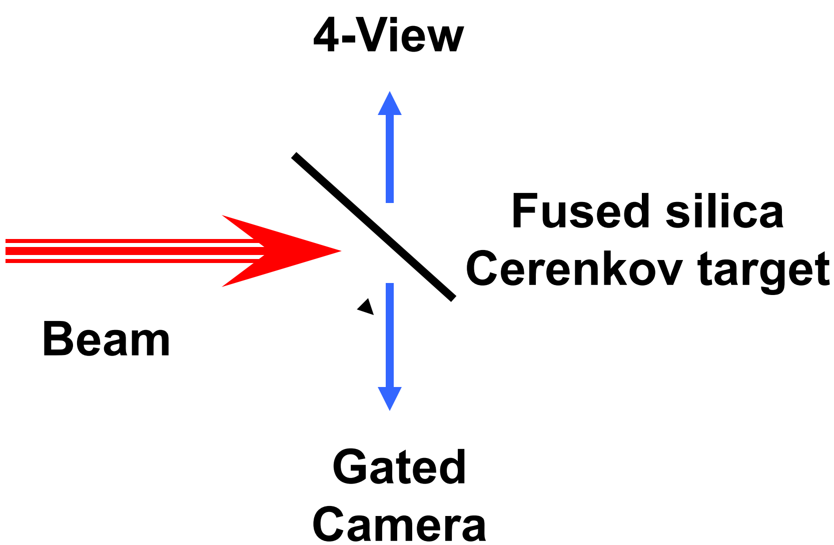
4-view streak images



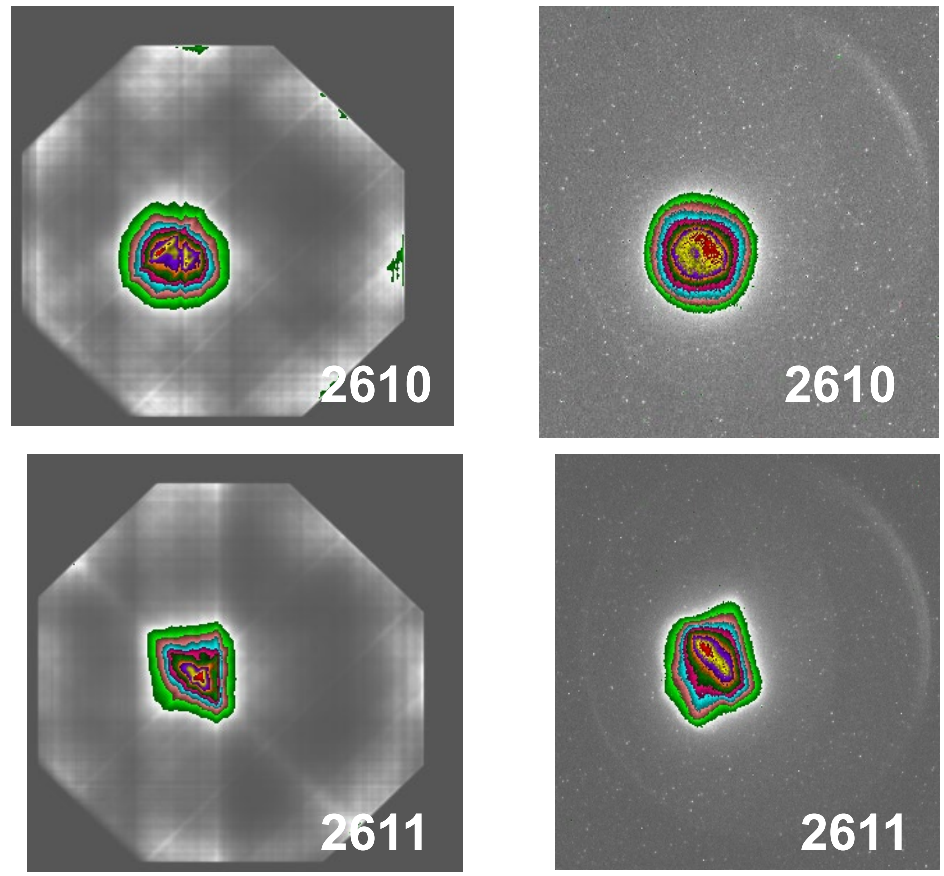
Reconstruction Movie

Maximum-entropy tomographic reconstruction of time slices from the four streaks agree with simultaneous gated-camera images.

Reconstructions were compared with simultaneous single-frame images taken from the opposite side of the fused-silica Cerenkov target.



4-View reconstruction | **20-ns gated PiMax Image**



Summary of progress on TRSS :

- **TRSS assembled and tested in multi-pulse mode for 2 days on the 8-MeV DARHT-II accelerator (December, 2006 and February, 2007)**
  - **Camera control and timing was excellent**
  - **PIMax-2 camera star rejection was excellent**
  - **Tungsten box shielding was acceptable**
  - **Integral scintillator/anti-scatter grid significantly suppressed the scatter background**
  - **Pinhole blur (PSF) acceptable for < 2-mm 50%MTF spots**
- **TRSS-Lite tested for ? days on DARHT-I**
  - **Vessel shielding with bare cameras was demonstrated to be acceptable**
  - **Uses same pinhole, but mounted in inner vessel shielding**
  - **Uses same scintillator, optics, cameras**
  - **Axis 1 slice and dice September 4-7**
- **Axis 2 multi-pulse target measurements scheduled to begin November 15**